there was never a Univac IV. Some Univac III customers, such as the Connecticut Department of Transportation and the Modern Woodmen of America, did convert to the Univac 1100 series machines. Others, including U.S. Steel, switched to other computer vendors.

Conclusion

As a late entrant in the general-purpose transistor computer market, Sperry Rand was able to produce relatively sophisticated products in the Univac 1107 and the Univac III. The drawback was that late entry resulted in a much lower sales volume than that of key competitors. Fortunately for Sperry Rand, the smaller Univac 1004, 1005, and 1050 computers it developed at the beginning of the 1960s were sales successes. The delays in producing the large transistor machines would have left the company without a product for a couple of years were it not for the other product lines. The smaller computers helped bring in revenue to keep the company alive until deliveries of the Univac 1108 began in the later 1960s. While the development of the original Univac line came to an end with the Univac III, the Univac 1107 served as the point of departure for the 1108 and later computers in the Sperry Rand (and Unisys, after the 1986 merger with Burroughs) 1100 and 2200 series. The Univac 1107 is now embodied in the Unisys ClearPath HMP IX. Today's ClearPath HMP IX computer can still run assembly language programs written for the 1107. So, this product line from the 1960s lives on at some 3,000 sites worldwide.

Notes and References

[1] D.E. Lundstrom, *A Few Good Men From Univac*. Cambridge, Mass.: MIT Press, 1987, p. 20.

[2] H. Lukoff, *From Dits to Bits: A Personal History of the Electronic Computer*. Portland, Ore.: Robotics Press, 1979; C.E. Leith, Jr., "Scientific Applications for the Univac LARC," *Proceedings of the 1961 Computer Applications Symposium*. New York: Macmillan, 1962.

[3] Frances Holberton Interview (CBI 50). Charles Babbage Institute, Univ. of Minnesota.

[4] B. Goody Katz and A. Phillips, "The Computer Industry," R.R. Nelson, ed. *Government and Technical Progress*. New York: Pergamon Press, 1982.

[5] E.D. Zimmer, "The X-308 Computer," *Proc. Symp. New Computers: A Report From the Manufacturers*, ACM, Los Angeles Chapter, Los Angeles, 1957.

[6] David Lundstrom gives a detailed account of the NTDS project in chapters 5-7 of *A Few Good Men From Univac*.

[7] Information on the 490 is taken from George Champine's draft chapter in an unfinished history of Sperry–Univac computers in the Sperry-Univac Archives at the Hagley Library, Wilmington, Del., and from Auerbach Corporation's *Standard EDP Reports* (1968).

[8] Information on the 418 also comes from George Champine's draft chapter and Auerbach's *Standard EDP Reports*.

[9] Robert E. McDonald Deposition (16-18 July 1974), Sperry Univac Archives, Hagley Library, Wilmington, Del.

[10] "An Examination of the Participating Lease Plan as Applied to the Univac III Program" (20 August 1964), Sperry Univac Archives.

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Howard Aiken on the Number of Computers Needed for the Nation

I. BERNARD COHEN

According to a remark by Howard Aiken, one that is often quoted, only a very small number of computers would be needed to serve the needs of the whole world, perhaps a dozen, with eight or 10 for the United States. Sometimes the number is given as six or even two or three. As we shall see, documentary evidence confirms that Aiken did, indeed, once say that one or two "computers" would suffice, but he was referring to a special kind of use and not to all possible needs for computer power in every aspect of activity in the whole of the United States. The context shows that his remark did not have the general context that may be supposed and that it was not, therefore, as incorrect as might at first appear.

Introduction

An early report on Howard Aiken's prediction concerning the number of computers (the first one I have found in print) appeared in the record of an interview with J. Presper Eckert, Jr., and John W. Mauchly published in *Datamation* in April 1962. The interviewer, Harold Bergstein (editor of *Datamation*), asked:

> "Who made the now classic prediction that the total requirement for computing power in the U.S. would be six machines?" Eckert replied that there was "some confusion" on this topic, a misinterpretation of what Mauchly had once said, which was: "Let's get orders for six machines to get us enough backlog to make it worthwhile to go ahead with the ENIAC project."

Although this is a correct quote from *Datamation*, it may well have been a misquote from what Eckert actually said—perhaps it should have been either "BINAC" or "UNIVAC" rather than "ENIAC."

Then, according to Eckert, "Howard Aiken made a remark that if six machines were built," we would "never be able to train enough people to program enough problems for these machines." As an aside, he observed that he did not "know" whether Aiken "was referring to the six machines we were building or whether he was referring to some other source." Eckert remarked, in conclusion, that Aiken "was thinking in terms of just hand programming" and did not "take automatic programming into account." These comments show that Eckert was aware of Aiken's argument about the limitation of the number of mathematicians available for programming.

In the ensuing discussion, Mauchly said he believed that Aiken had not taken

> into account the fact that some of these machines would be devoted to repetitive tasks such as running payrolls weekly, for which you can keep these machines busy without large programming efforts producing new problems all the time.

Eckert enlarged on this comment:

> "I don't think," he said, that Aiken "thought of sorting and collating and file maintenance and all that sort of thing which take up hours and hours of time on these machines," during which time "you're not really doing any computing in the ordinary sense of the word."

At the time of the interview, in 1962, Mauchly and everyone else in the computer community were aware of Aiken's constant and public stress on the problem of the shortage of mathematicians and the consequent limit on the number of computers that could be put into use. Mauchly had been present at the 1947 *Symposium on Large-Scale Computing Machinery*, organized by Aiken (see Fig. 1) and held at Harvard, and had given one of the main papers. Aiken devoted part of his concluding remarks to an announcement of his intention to establish at Harvard an academic program in computer science that would help to alleviate the shortages in trained personnel.[1]

The shortage of mathematicians who were needed to program all the new machines was a constant theme in Aiken's discussions during the late 1940s and early 1950s. In 1950, at a conference held in Cambridge, England, on *High-Speed Automatic Calculating Machines*, Mr. W.S. Elliott gave a first-hand report of a conversation with Aiken. Aiken's Mark II calculator, Elliott noted, is "300 or 400 times faster than the Mark I calculator and six men are kept busy preparing problems for the Mark I." He quoted Aiken as having said in this regard, "If all the machines now being built are completed, there would not be enough mathematicians to run them."[2]

In retrospect, what may be most interesting about the dialogue published in *Datamation* is that none of the three who participated—not Eckert or Mauchly or Bergstein—was aware that there

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had been an even more dismal Aiken prediction concerning a need for only two or three large-scale computing machines. This prediction had been made 13 years earlier in 1949, in the course of a private conversation. It was recorded at the time by Edward Cannon, but Cannon apparently did not make public his notes about Aiken's prediction until 1973, 11 years after the interview with Eckert and Mauchly. The occasion was his giving testimony in the famous trial of *Honeywell v. Sperry Rand*. The date of Aiken's prediction—as recorded by Cannon—was March 1949, before any computing machines that made use of the stored-program concept were in regular operation.

Fig. 1. Howard Aiken examining a portion of Babbage's Difference Engine.

Photo courtesy of Harvard University Cruft Photo Laboratory

Aiken's prediction was made after a meeting of a subcommittee appointed by the National Research Council of the National Academy of Sciences. This group, officially called Subcommittee Z on High Speed Computing, was chaired by John von Neumann.[3] The specific assignment of the subcommittee was to evaluate three computer projects under consideration by the National Bureau of Standards. These had been submitted by:

- the Electronic Control Company of Philadelphia (organized by Eckert and Mauchly),
- the Raytheon Manufacturing Company, and
- the Moore School of Electrical Engineering of the University of Pennsylvania.

The immediate prospective user of such a computer ("high-speed computing machine") named in the subcommittee's report was the Bureau of the Census, which had been interested in the work of Eckert and Mauchly and the possibility of using a post-ENIAC type of machine.

The Bureau of the Census, however, was not permitted to fund development work; for this reason, all arrangements for a possible new computer were to be made through the Bureau of Standards. The Bureau of the Census wanted information on two specific questions relating to a proposed computer to be made by Eckert and Mauchly: an appraisal by experts on the practicality of an Eckert–Mauchly machine and assistance on specifications to be made in any contractual arrangement if the proposal was a sound one.[4]

John H. Curtiss of the Bureau of Standards was pleased with the proposed assignment to subcommittee Z. He was aware of the needs of his own bureau in this domain, and he saw the action of this subcommittee as an opportunity to strengthen the bureau's position as the central patron in the development of the new computing machines for various government agencies. In 1946, $300,000 had been transferred from the Army Ordnance Department to the Bureau of Standards for the development of a computer. Before long, bids and proposals were solicited, and three rival systems were put into competition.[5] Two of these had a similar origin: one was from the Moore School, where Eckert and Mauchly had been on staff during the first discussions with the Bureau of the Census; another came from the new company formed by Eckert and Mauchly, who had left the Moore School. Raytheon submitted the third proposal.

Thus, when the Bureau of Standards turned to the National Research Council for technical advice, there were three rival proposals to be evaluated. According to Nancy Stern, the historian of UNIVAC, the bureau hoped that in the final report of the subcommittee, some comparative information would also be made available. Subcommittee members included George Stibitz (formerly of the Bell Telephone Laboratories), von Neumann (Institute for Advanced Study), Samuel Caldwell (MIT), and Aiken (Harvard). The machines in question were:

- the Bell Laboratories series of relay machines,
- the IAS machine at Princeton Institute (under construction),
- the Whirlwind at MIT (under construction), and
- the Harvard machines.

This list thus includes at least seven machines (or families of machines), five of which were being planned to be stored-program computers. An important part of the subcommittee's assignment was to consider not only the three rival proposals of specific machines but also the program of ordering five new stored-program computers.[6]

The subcommittee's report, dated 16 March 1948, however, dealt only with the machines proposed by Eckert and Mauchly, by Raytheon, and by the Moore School, all three of which were planned to be "computers" in some important senses in which we use that term today. From the point of view of the Bureau of Standards, the report was apparently unsatisfactory because of the absence of any comparative evaluations of the IAS, the Harvard machines, or Whirlwind. The subcommittee also reported on various policy issues concerning the activities of the Bureau of Standards in developing computers.

The subcommittee met on 9 March 1948 in Cambridge, Massachusetts. All four members were present, as well as Curtiss.[7] The report (written by von Neumann) took note that many design features of the three proposed machines were basically the same. Accordingly, these three machines—in the words of the subcommittee's report—did not represent "three really different and independent intellectual risks." A major point made by the report was that "a choice between the three proposals, on a primarily technical basis, is hardly possible." The reason given was that the progress reports of the three rival groups did "not show to what extent the essential componentry that is being described has been developed, submitted to life tests and found reliable under the conditions which the computing machine would have to use it." Also, there was not any real information concerning "what the realistic estimates" would be "of the time and the expenditures involved."

The final part of the report is especially significant in view of Aiken's remark about the number of such computers needed. It was noted that the "Bureau has about $900,000 available to build five computing machines." Thus, "the amount available for one computing machine is $180,000." But the estimates given by the three "proposed contractors" quoted "prices for machines based on the Bureau's specifications," which were as high as "$650,000 per machine."

Because Aiken had an "extraordinary ego," Auerbach concluded, he "just could not tolerate anybody not considering him *the* most eminent computer engineer in the world."

The report clearly and unmistakably concludes that the number of machines to be built should be fewer than five. The report also concludes that the contractors should go back to the drawing board. One conclusion would seem to be that perhaps the overall specification of the machines was too all-inclusive (too "general purpose") for the specific needs of the Bureau of the Census. We shall see, in a moment, that Aiken's remark about the number of computers was made in this specific context.

The subcommittee's report stated that, in view of the complex nature of the planned "computing machines," the first step should be to produce a set of working components, rather than a complete machine. The subcommittee members saw no evidence that "the essential componentry that is being described" had actually been "submitted to life tests, and found reliable under the conditions under which the computing machine would have to use it." The report stressed that "the design and construction of large-scale digital computing machines represent an art which is still in the research and development stage." Accordingly, it was "unwise at this time" to build a series of "duplicate calculating machines" and "even more unwise" to "initiate the building of a higher number of identical ones."

The subcommittee strongly recommended that a series of working components be developed. Then, after these had been fully tested, a decision should be made as to whether the new machine or machines should be assembled by the bureau or by one of the three constructors.

Isaac ("Ike") Auerbach, many years later, remembered that the committee concluded that "it was impossible to design and build a mercury memory that would operate in a computer."[8] At that time, Auerbach stressed, he and "Brad Sheppard had designed, built, and demonstrated such a memory." Auerbach said that he "never saw the report but I recall our surprise when we heard about" this conclusion. "All they had to do was get on a train and forty miles away in Philadelphia they could see a computer mercury memory operating." The committee should have stopped "conjecturing about the theoretical aspect of things"—they should have "just come down and [had a] look."

There is one further aspect of the background to Aiken's remark about the number of computers needed. The staff of the Bureau of Standards seems to have had a strong leaning to the proposal of Eckert and Mauchly. Indeed, it is a fact of record that the bureau did not follow the subcommittee's recommendations and in the end proceeded to support Eckert and Mauchly in the development of the UNIVAC series of machines.[9] This partiality of the bureau to Eckert and Mauchly is in strong contrast, as Stern has documented, to the evident strong bias of the subcommittee members against Eckert and Mauchly. This generally negative feeling, she found, could be traced back to the days of World War II, when the ENIAC project was not highly regarded by the experts; they considered that Eckert and Mauchly and their group were "naive and unsophisticated." Both Caldwell and Stibitz had displayed their negative attitude toward the ENIAC group in their official positions during wartime. Stern points out that von Neumann, even though he had been associated with Eckert and Mauchly during the days of the ENIAC, had become "particularly unsympathetic to Eckert and Mauchly"; von Neumann "regarded the commercial interests of these two men as unprofessional."

At this time, 1948, Aiken himself did not have a high regard for Eckert and Mauchly and the new company they had founded. Indeed, an example of Aiken's antipathy toward Eckert and Mauchly and their company has been recorded by Auerbach. While a student in Aiken's graduate program in computer science at Harvard, Auerbach got himself a job working for Eckert and Mauchly. When he told Aiken about his new position, Aiken abruptly ceased talking to him. For the rest of the year and for some time after he left Harvard, Auerbach became (in his own words) "a nonperson." This nonrecognition of Auerbach continued until he changed jobs and began to work for Burroughs. Then, Aiken warmly greeted him and introduced him as his protégé.[10] The event of Auerbach's becoming a nonperson to Aiken occurred during the winter of 1948, the same year in which Aiken expressed his apparently dismal prediction about the number of computers.

In an oral-history interview, Auerbach gave his explanation of why von Neumann and the committee had not bothered to find out what Eckert and Mauchly and their associates were doing. Auerbach referred to "the von Neumann/Eckert and Mauchly feud, which eventually broke up what was to become a joint venture." He traced the origins of the "major rupture" to von Neumann's "effectively [having] indicated that he was going to control the conceptual design of the next machine." As far as Aiken was concerned, Auerbach continued, he thought of Eckert and Mauchly as "the enemy" because "they had one-upped him," that is, he had been "one-upped by ENIAC, which kind of stole his thunder." Because Aiken had an "extraordinary ego," Auerbach concluded, he "just could not tolerate anybody not considering him *the* most eminent computer engineer in the world." Auerbach added, "von Neumann also had a supreme ego. I knew them both." The "only

other person" in that ego league "would be Norbert Wiener," but he was "a more modest man by comparison."[11] The magnitude of Auerbach's categorization of Aiken and von Neumann can be fully appreciated only by those who ever had personal contact with Wiener, for whom the word "modest" would be the least appropriate adjective in the English language.

This feeling of hostility toward Eckert and Mauchly, when coupled with the general attitude expressed in the subcommittee's report, provides a context for understanding Aiken's apparently gloomy prediction about the number of computers. Aiken's statement about the computer needs was made at the time of a meeting of the subcommittee,[12] but not during the formal sessions. It was recorded by Cannon, Curtiss's assistant.[13] According to Cannon's memorandum, Aiken "expressed to the two of us in a rather pontifical manner that we were misleading the government and public" by "trying to provide for the development of large computers of the type we were interested in." The "reason" Aiken gave, according to Cannon, was that "there never would be enough work for more than two of these computers." Accordingly, "rather ought we to turn to assisting in the development of small, desk-sized computers." Cannon noted that this was not a "conversation" with Aiken; rather, a "sermon by Dr. Aiken is the best description."[14]

Aiken was not discussing large-scale computing machines in general, but rather the specific types of machine under consideration by the Bureau of Standards.

Aiken was recorded to have declared, furthermore, that "we" (that is, the subcommittee) would be "misleading not only the government agencies which had made money available for development of such equipment, but the general public in pursuing the course of trying to develop such equipment, giving the impression that this program could be justified." The reason, Aiken is said to have argued, was "that there will never be enough problems, enough work for more than one or two of these computers." Accordingly, Aiken concluded by telling Cannon and either Curtiss or Alexander (and the National Bureau of Standards) "to go back and change your program entirely," to "stop" this "foolishness with Eckert and Mauchly." The Cannon memorandum, with its quotation of Aiken's opinion, assumed historical importance when Cannon read it in his testimony in the celebrated trial of *Honeywell v. Sperry Rand* (p. 17,935).

The bluntness of Aiken's reported language and the description of his style (e.g., "pontifical manner" and "sermon") testify to the accuracy of the report. In order to understand what Aiken had in mind, we must take into account that he was talking in the context of the meeting of the subcommittee. The purpose of the subcommittee was to deal with computers, with the new breed of digital stored-program machines, with actual "computers" in very nearly the present accepted sense of that term. Aiken certainly knew of at least two such large-scale stored-program machines in the process of being designed and built in the United States—von Neumann's IAS machine and Jay Forrester's Whirlwind. Two members of the subcommittee (von Neumann and Caldwell) were associated, respectively, with these two machines.

An analysis of the words that Aiken actually said and a consideration of the context help to make Aiken's meaning clear. First of all, he said that the bureau was "misleading the government and [the] public" by its activity with regard to the "large computers of the type we were interested in." This would indicate that Aiken was not discussing large-scale computing machines in general, but rather the specific types of machine under consideration by the Bureau of Standards. Recall that the bureau's proposal called for five such machines. Aiken said—these are his very words as recorded by Cannon—that "there never would be enough work for more than two of these computers." The specific reference implied by the word "these" ("these computers") permits little doubt, therefore, that Aiken was not making a prediction about the work to be done in every aspect of computer work in the country, but was referring specifically to the proposed computers ("these computers") that would be used by the Bureau of the Census or possibly the Bureau of Standards. Two of the new breed of computers would suffice for these bureaus, Aiken concluded. It was for this reason that he recommended "the development of small, desk-sized computers." In retrospect, then, this first part of Aiken's recorded statement is in no sense completely absurd, as would seem to be the case by quoting it out of context and as if it applied to the total computing needs of the nation.

The interpretation I have just given is reinforced by Aiken's next remark—to the effect that "we" would be "misleading" both the government and the public by "giving the impression" that "this program" (that is, the program of building five of the new kind of computers) "could be justified." In support of his position, he argued that "there will never be enough problems, enough work for more than one or two of these computers." As has just been mentioned, in context "these computers" clearly refers to the computers to be built for the Bureau of the Census and the Bureau of Standards, not the number of such computers for every imaginable purpose in the United States. His advice, therefore, to the staff of the bureau was to design a wholly new program and to abandon the "foolishness" of the current negotiations with Eckert and Mauchly.

One part of Aiken's reported statement to Cannon is of special interest: his prediction that there might not be "enough problems, enough work" to keep new high-speed machines busy. At the time of the meeting of the subcommittee, there seems to have been a somewhat widespread feeling that computers of this new breed might work so quickly that they would soon run out of problems to keep them busy.

The evidence for the prevalence of such a belief is found in a talk given in November 1949, the year following the subcommittee sessions when Cannon had recorded Aiken's remarks. The speaker was von Neumann, the chairman of the subcommittee that investigated the computer needs of the National Bureau of Standards. The occasion was an *IBM Seminar on Scientific Computing*, at which von Neumann spoke about "The Future of High-Speed Computing."[15]

At the seminar, von Neumann began by noting a "major concern which is frequently voiced in connection with very fast computing machines." There was a fear, he said, that because of "the very high speeds which may now be hoped for," these machines "will do themselves out of business." That is, these new machines "will out-run the planning and coding which they require and, therefore, run out of work." Accordingly, although von Neumann did not say so specifically, the implied reaction to this fear would be that it would be unwise to build very many such machines.

Therefore, von Neumann's own position on this question is of great interest. He began by noting that for "problems of those sizes which in the past—and even in the nearest past—have been the normal ones for computing machines," the actual "planning and coding required much more time than the actual solution of the problem, even on one of the hoped-for extremely fast future machines." But, von Neumann pointed out, "the problem size was dictated by the speed of the computing machines then available." An equilibrium was eventually reached, von Neumann believed, when the problem time became relatively longer ("but not prohibitively longer") than the "planning and coding time." In other words, new problems of greater complexity were being (and would be) addressed by the machines.

But von Neumann also knew that the argument for needing only a few machines was based on the need to solve problems on the scale and of the sort then being solved on existing machines.

With the new fast machines, von Neumann argued, there would be the same kind of "pressure," acting like an "automatic mechanism," a "pressure toward problems of larger size." He envisioned that there "will be a year or two, perhaps, during which extremely fast machines will have to be used relatively inefficiently while we are finding the right type and size [of] problems for them."

von Neumann obviously did not anticipate the production of programming languages that would radically alter the ratio between the planning and coding time and the problem-solving time. In the present context, the significant point of von Neumann's rebuttal is that he was fully aware of an envisioned limitation in the potential use of the future computers, of the predicted possibility that they might "run out of work." But von Neumann also knew that the argument for needing only a few machines was based on the need to solve problems on the scale and of the sort then being solved on existing machines. von Neumann was aware that the new generation of proposed high-speed, electronic, stored-program computers, such as those being constructed at the IAS and MIT and those being considered for the National Bureau of Standards, would produce a radical change in the type, size, and scale of problems. That is, wholly new ranges of problems would be brought to the computer, which up until then had been ruled out of consideration because of their complexity and scale. Those who saw a limited future for high-speed computing machines erred in not taking this important factor into consideration.

Aiken's position with respect to the new high-speed computers was not so rigidly narrow as has often been supposed. We can gain some insight into his point of view from a feature story about computers that appeared in the issue of *Time* magazine for 23 January 1950, about one year after von Neumann's talk. This story was, in large measure, based on an interview with Aiken that must have taken place late in 1949 and so, only a year or more after Aiken's remarks were recorded by Cannon. The article took note of the increasing speeds in the sequence of Aiken's machines. Mark II, it is said, "is ten times as fast as Bessie" (the name by which *Time* referred to Mark I), while "Mark III is 25 times as fast as Mark II." The "machines now building will be faster still." Evidently, Aiken was asked what would be the consequences of this increased speed. He is quoted as having said, "We'll have to think up bigger problems if we want to keep them busy." This statement would seem to reinforce the interpretation that Aiken's response to the advent of high-speed computers was not that one or two of them would suffice for all the computing needs of the nation. Rather, his considered response to this dilemma was similar to von Neumann's: "to think up bigger problems."[16]

In 1952, four years after Cannon recorded Aiken's remarks and three years after von Neumann's presentation to the *IBM Seminar on Scientific Computing*, Aiken himself discussed this issue of the change in the type of problems for which "computing machines" were used. The occasion was a pair of talks—one given at Fairleigh Dickinson College, the other at the Harvard Business School (the Harvard Graduate School of Business Administration).[17] Speaking six years after ENIAC had become operational, Aiken contrasted the perceived goal and actual assignment of the early "calculating machines" and the new computers. At first, he recalled, "there was no thought in mind that computing machines should be used for anything except out-and-out mathematics." He stressed this feature of the early machines by saying, "I do not exaggerate when I say that everyone in any way connected with the original development of large-scale computers had in mind only one thing—namely, the construction of machines for the solution of *scientific* problems."

In discussing this topic, Aiken admitted that "no one was more surprised than I when I found out that these machines were ultimately to be used for control in business." He and others had designed and constructed machines to solve differential equations or systems of differential equations or produce tables of functions. These problems came from engineering, the sciences, and—to some degree—the social sciences (e.g., economics) and statistics. "Originally one thought," Aiken reminisced, "that if there were a half dozen large computers in this country, hidden away in research laboratories, this would take care of all requirements we had throughout the country."[18]

This is the only reference I have ever found to Aiken's having specifically referred (in a public talk, a manuscript text, a letter, or an edited statement) to the need for only a limited number of large-scale "computing machines." The phrase Aiken used ("Originally one thought...") would seem to indicate that this point of view was rather commonly held, but does not tell us specifically whether Aiken himself was thinking along these lines.

In both the talk given at Fairleigh Dickinson and the one at the Harvard Business School, Aiken went on to explain the proliferation of computers. These were no longer restricted in their use to the solution of mathematical problems. As Aiken was at some pains to explain to his audiences, vast new areas of application had been discovered. These included:

- data processing,
- commercial billing and control,
- statistical analyses,
- automation in business and manufacturing, and
- machine translation from foreign languages.

In other words, the new computers were not limited in their uses to the original domains of science and engineering for which the first "computing machines" had been designed, but were being applied to a constantly expanding series of new uses.

In retrospect, it would seem that Aiken's remark to Cannon was in part an expression of his personal disdain for Eckert and Mauchly. But, as the foregoing analysis shows, predictions about the number of computers should be read in context and not displayed as general statements about all the future computer needs of the country. Aiken did not deny the fecundity of his own brainchild.

References and Notes

[1] *Proc. Symp. Large-Scale Digital Calculating Machinery*, jointly sponsored by Navy Dept. Bureau of Ordnance and Harvard Univ. Computation Laboratory, 7–10 Jan. 1947, Cambridge, Mass.: Harvard Univ. Press, 1948, vol. 16, *Annals Computation Laboratory of Harvard Univ.* (Reprinted, with a new Introduction by W. Aspray. Cambridge, Mass., and London: The MIT Press; Los Angeles and San Francisco: Tomash Publishers, 1985. Charles Babbage Institute Reprint Series in the History of Computing, vol. 7.)

[2] University Mathematics Laboratory, Cambridge: *Report on High Speed Automatic Calculating-Machines, 22–25 June 1949* (Issued by the laboratory with the Co-operation of the Ministry of Supply, January 1950); this volume was reprinted, along with others, in M.R. Williams and M. Campbell-Kelly, eds., *The Early British Computer Conferences*. Cambridge, Mass., and London: The MIT Press; Los Angeles and San Francisco: Tomash Publishers, 1989. Charles Babbage Institute Reprint Series for the History of Computing, vol. 14, p. 152.

[3] On the background of these events, see N. Stern, *From ENIAC to UNIVAC—An Appraisal of the Eckert–Mauchly Computers*. Bedford, Mass.: Digital Press, 1981; and W. Aspray, *John Von Neumann and the Origins of Modern Computing*. Cambridge, Mass., and London: The MIT Press, 1990.

[4] Information concerning the Bureau of the Census and the National Bureau of Standards in relation to the background of this subcommittee's activities is drawn from the books of Stern and Aspray, cited above.

[5] Stern, op cit..

[6] Ibid.

[7] The following account of the meeting of the subcommittee is based largely on a draft report (of which a copy may be found in the Aiken files in the Harvard University Archives) of the Cambridge meeting. There may have been other meetings as well.

[8] Interview conducted by B. Brummer; a transcript is available in the Charles Babbage Institute.

[9] Stern, op cit.

[10] For details, see E. Weiss's fine eloge of Auerbach in these *Annals of the History of Computing*, vol. 15, pp. 60–61, 1993. As mentioned in note 9 supra, a transcript of the interview is on file in the Charles Babbage Institute. More information on Auerbach's relations with Aiken and on Aiken's views concerning Eckert and Mauchly can be found in I.B. Cohen, *Howard Aiken—Portrait of a Computer Pioneer*. Cambridge, Mass., and London: The MIT Press, 1998.

[11] See note 9 supra.

[12] As I have indicated, I know of no way to determine whether Aiken's remark was made after the Cambridge meeting or after another meeting of the subcommittee, perhaps in Washington, D.C.

[13] It is not clear whether Aiken's remark was made to Cannon and Curtiss or to Canon and Samuel Alexander.

[14] These transcripts were made available to me through the generosity of Paul Ceruzzi. The originals are to found in the Eleutherium Mills/Hagley Museum in Wilmington, Del.

[15] See W.J. Aspray and A. Burks, eds., *Papers of John von Neumann on Computing and Computer Theory*. Cambridge, Mass., and London: The MIT Press; Los Angeles and San Francisco: Tomash Publishers, 1987. Charles Babbage Institute Reprint Series in the History of Computing, vol. 12.

[16] In the course of an oral-history interview with Aiken, conducted by Henry Tropp and me in the autumn of 1973, just weeks before he died, we asked Aiken directly about the statement of the need for only a limited number of computers. He began to answer, referring to von Neumann's ideas, and then—as so often happens in interviews—the subject shifted, and we never got back to this topic.

[17] Partly edited transcripts of both of these talks are available in the Aiken files of the Harvard University Archives. These texts are, for the most part, published in I.B. Cohen, G. Welch, and R.V.D. Campbell, eds., *Making Numbers—Howard Aiken and the Computer*. Cambridge, Mass., and London: The MIT Press, 1998.

[18] This sentence occurs in the Fairleigh Dickinson transcript, but not in the Harvard Business School version.

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The Math Tables Project of the Work Projects Administration: The Reluctant Start of the Computing Era

DAVID ALAN GRIER

The Mathematical Tables Project, one of the last large human computing groups, began operation in 1938 as a WPA project in New York City. Unlike preceding computing organizations, the Math Tables Project mass-produced calculations using unskilled labor. Prior to 1938, most hand computing organizations used well-educated computing assistants who could operate independently. Over its 10-year history, the Math Tables Project completed 28 published volumes of tables and calculations for dozens of scientific and war projects. During World War II, it acted as a general computing contractor for the Office for Scientific Research and Development and prepared LORAN Navigation Tables for the Navy. After the war, it was absorbed by the National Bureau of Standards. It proved to be a transitional institution in the history of computing, promoting mass scientific computation and developing the numeric methods that would eventually be used on electronic computers.

Introduction

When the Work Projects Administration (WPA) decided to establish a large hand computing organization in the winter of 1938 as a means of creating jobs for unemployed office-workers in New York City, few scientists took serious notice, assuming that such a group could accomplish little. To most researchers, no progressive organization could employ 450 human computers[1] to calculate a series of mathematical tables by hand. At most laboratories, hand computation had long been superseded by logarithm tables, slide rules, mechanical desk calculators, and, in the most modern facilities, punched card equipment. At the Naval Observatory, one of the larger employers of human computers, workers had been using a variety of calculating aids since the 1880s. Yet from this inauspicious relief effort came the Math Tables Project, one of the largest and most active scientific computing organizations before the electronic computer era. More than any other computing organization of the 1930s, the Math Tables Project was responsible for developing, cataloging, and promoting the methods of large-scale, mass scientific computation.

The Math Tables Project was one of approximately two dozen scientific computing organizations that operated during the first four decades of this century. These groups evolved in a manner that paralleled the development of U.S. industry during the same period. Just as the end of the 19th century saw factories change from small machine shops to large assembly lines, so the early years of the 20th century saw scientific computing organizations evolve from small groups of well-trained computers to large facilities of modestly educated individuals who mass-produced scientific computations.

The Math Tables Project pioneered the last stage in the development of mass computation before the advent of electronic computers. Like the killing floors of the meatpackers or the assembly lines of Henry Ford, the Computing Floor of the Math Tables Project (see Fig. 1) divided complex tasks into their component pieces and assigned to each piece an unskilled worker. The scientific computing groups that preceded the Math Tables Project all employed computers who were at least semiskilled, who had enough mathematical education to be able to understand the calculations they were undertaking. By contrast, the project[2] employed computers with little education, and who understood no more than the rudiments of arithmetic. Project computers would usually perform only a single operation, such as addition or multiplication. The managers of the Computing Floor would use worksheets to control the computations. These worksheets would pass from computer to computer, as each worker would complete his or her operation on the appropriate pair of numbers. At the day's end, the managers would gather the worksheets together and collate the results into a table.

Despite the obvious parallels between the Computing Floor and industrial assembly lines, the Math Tables Project was shaped more by the idealism of the age and the personal drive of its leaders than by the profit motive or by the demands of the marketplace. The project was never a profitable activity and always required government subsidy. The income generated by the sales of tables covered neither the wages of the computers nor the costs of preparing the worksheets.[3] The project reflected the idealism of President Franklin Roosevelt's New Deal. Like many WPA projects,

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